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RESERVOIR MALARIA CONTROL AND SANITATION PROBLEMS

by Frank B. Wood, A.M. ASCE

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RESERVOIR MALARIA CONTROL AND SANITATION PROBLEMS

Frank B. Wood,[1] ASCE

SYNOPSIS

Reservoirs have sanitary engineering problems. These problems and their importance vary considerably with the location, use and characteristics of the reservoir. It is important to recognize the problems during the planning stage and the management of reservoirs should include adequate measures for safeguarding the health of the nearby residents and the visitors to the area. Reservoir operation, especially the release of water relatively free of organic material, is often beneficial in connection with minimizing the effect of pollution below the dam.

INTRODUCTION

Reservoirs have been and are being developed for many purposes. Formerly the majority of the reservoirs were for one purpose such as power production, irrigation, water supply, navigation, flood control. During World War I the Wilson Dam and Reservoir project on the Tennessee River was constructed for electric power production and navigation. Since 1930 many of the reservoirs, especially those being developed by the Federal Government, are of the multiple-purpose type with combinations such as navigation, power production and flood control.

Practically all reservoirs have management problems including some involving sanitary engineering. The shorter work week, vacations with pay and better and faster modes of travel have resulted in a great increase in the use of reservoirs and adjacent areas for recreational purposes. Upward of a million visitors a year to the Allatoona Reservoir, near Atlanta, Ga., four million to Lake Texoma near Dennison, Texas; and approximately thirty million a year to Corps of Engineers Reservoirs indicate the recreational importance of reservoirs.

General

The reservoir problems in the sanitary engineering field should be considered in the early study and planning stage, not neglected during construction, and not forgotten after the project is completed. There have been instances where improper planning, development or operation of reservoirs have resulted in serious outbreaks of malaria with much suffering and some deaths. Fortunately, the development and operation of reservoirs have been improved and there has been practically no evidence of malaria transmission

1. Engineer, Chief Reservoir Sanitation Section, Master Planning Branch, Engineering Division, South Atlantic Division, Corps of Engineers, Department of the Army, Atlanta, Ga.

in the vicinities of reservoirs since about 1945. This cannot be attributed entirely to the care taken with reservoirs as the incidence of the disease has also decreased to the vanishing point in the United States, including many areas where the disease was formerly prevalent and where there has been no malaria control program. However, the findings do indicate that the many new reservoirs have not resulted in an increase in the incidence of the disease.

Coordination

The individual, corporation or agency planning a reservoir should confer with representatives of the Health Department of the state in which the project is located to obtain information on the probable health problems involved. Practically all the southeastern states where malaria was formerly endemic have laws or regulations with the effect of laws governing the impounding of water. These laws or regulations are directed at preventing the creation of man-made malaria hazards or at least at preventing an increase in the incidence of malaria within the vicinity of artificially created bodies of water. The health agencies are also interested in environmental sanitation, facilities for swimming, and pollution abatement.

Malaria Control

The malaria problem of reservoirs has been given major consideration especially in the southeastern states. The state laws or regulations, the majority of which were adopted between 1920 and 1930, were based on earlier studies of outbreaks of malaria in the vicinities of new reservoirs. They took into consideration the equipment, methods and materials of that period available for the preparation and maintenance of reservoirs and for mosquito control, estimated flight and transmission ranges of the vector mosquito and other factors. The majority of the regulations require the complete clearing of all portions of a reservoir that are within one mile of resident population other than the owner. Marginal clearing for a distance of 25 feet from the water's edge was initially required but later this distance was reduced to 10 feet, and presently marginal clearing plans take into consideration the ground slopes, anticipated wave erosion, type of growth, anticipated water level stages, proposed shore line modification and methods to be used for applying larvicides.

Plans for preventing a reservoir from increasing the malaria hazard of the area often include one or more of the following recognized procedures:

a. Clearing of the zone extending from one foot or more below the minimum water level up to the normal summer time operating level with the non-water tolerant growth being removed up to an elevation one or more feet above the summer operating level.

b. Permitting no night use during the mosquito breeding season of all land within one mile of uncleared portions of the reservoir.

c. Constructing dams or dikes to separate the reservoir from arms or embayments that would be flooded to a shallow depth and keeping the shallow areas dewatered with pumps during the mosquito breeding season.

d. Eliminating areas to be flooded to a shallow depth by deepening a portion of the areas and filling the other portions.

e. Draining of all ponded and marshy areas in the zone of fluctuation.

f. Incorporating in the operation of the reservoir provision for water level management.

g. Maintaining the reservoir, especially the marginal areas, practically free of objectionable vegetation, drift and flotage.

h. Applying larvicides effectively to all areas within one mile of resident population or developments having facilities for overnight use.

i. Mosquito-proofing all dwellings within one mile of the reservoir.

j. Treating all buildings within one mile of the reservoir with a spray having a residual effect on mosquitoes.

Clearing: The cost of clearing a reservoir represents a relatively large percent of the total cost of a project. Often in the past it has been assumed that clearing is only needed for malaria control but this is a misconception. Clearing is also needed for commercial navigation, recreational boating, protection of project structures, reservoir operation and general appearance. In developing a clearing plan, all of these recognized needs for clearing should be considered. The use of overlays showing the clearing for the various purposes is helpful. Clearing for malaria control requires a cut-off only one foot below the minimum summer water level, whereas that for recreational boating and commercial navigation requires lower cut-offs, at least four feet for the former and ten or more feet for the latter.

There has been a gradual improvement in the methods of land clearing and it is now general practice to cut the trees and stumps within 6 inches or less of the ground. This is due primarily to the availability of portable power saws for felling the trees and to heavy equipment suitable for piling the felled material. Low stumps permit machine piling, improve boating near shore and do not support sprouts as well as higher stumps do.

It has recently been determined that trees can be economically topped a short distance above the water surface from skiffs and small barges; also, that if topped while the tree is in an active growing stage the majority of the tops sink. This procedure is especially applicable to the deep type reservoirs of mountainous regions and permits a reduction in the time required for clearing. The use of this procedure on the Blakely Mountain Reservoir near Hot Springs, Arkansas, resulted in a saving of approximately $250,000.

Relatively crude underwater saw rigs have been used to cut trees below the water surface. The Corps of Engineers is interested in the development of efficient equipment for cutting trees below the draft of the boat on which the equipment is carried as it is believed that such equipment can be used advantageously for stream bank clearing and certain tree topping operations for reservoir preparation. Ponded and marshy areas of reservoirs can often be cleared most economically by the topping procedure when the reservoir is partially filled. If the topping is performed before the trees are killed from inundation, very little material will have to be disposed of by burning or by other costlier methods of disposal.

The unit cost of complete clearing varies with the terrain, type and size of growth. Cutover upland forest clearing costs about $75 per acre, whereas bottomland hardwood forest of medium size trees costs about $125 per acre and heavy hardwood forest and stream bank clearing costs $200 or more per acre.

Restricting Land Use: This method can be applied to portions of reservoirs where the resident population is agreeable, especially if the land values are low. To date the Corps of Engineers has not acquired land or rights on land for this particular purpose but the merit of this procedure is recognized. The procedure involves the restriction of the use of all land within one mile of reservoir areas to be left uncleared to daylight hours during the mosquito breeding season. It has been proposed for two portions of the Jim Woodruff Reservoir, as the taking line for project purposes permitted the use of this procedure, with an estimated saving of $1,000,000.

Shore Line Modification: The construction of dams and dikes to separate shallow flat arms or embayments from the main portion of the reservoir and keeping the smaller portions dewatered with pumps during the mosquito breeding season has been utilized advantageously on some projects. The dewatered areas do not have to be cleared and portions of the areas can be used for agricultural purposes. In some instances the areas dewatered during the summer are utilized for growing water-fowl foods as the areas can be reflooded in the late fall.

Elimination of areas to be flooded to a shallow depth by deepening and filling reduces the mosquito breeding potential, reduces evaporation, increases the land area suitable for pasture and improves the flooded area for fish life.

Drainage: Drainage of ponded and marshy areas in the zone of drawdown is advisable especially if the larviciding is to be performed from boats or by sprayers carried by men. However, if the larvicide is to be applied from an airplane, drainage in the zone of drawdown may be more expensive than the larviciding of the areas. This is particularly true for the portion of the zone of drawdown that is dewatered for only short periods during the mosquito breeding season. The ditches should be properly located and constructed whereby maintenance will not be excessive. Dynamite is often used in the marshy areas but draglines are the most suitable equipment for the larger ditches. Drainage of ponds is often beneficial in preventing the stranding of fish when the water level recedes.

Water Level Management: Water level variations can be utilized to greatly reduce the mosquito breeding potential of a reservoir. In fact, this procedure is the principle mosquito control method being used on many reservoirs. The type of water level variation and the amount of variation depend on the location of the reservoir, its purpose, its topography, its size, inflow, discharge requirements and other factors. The most suitable water level management includes a late winter or early spring surcharge of one to three feet to strand drift and flotage above the normal operating level and minimize the sprouting of seed of objectionable plants; then rapid recession to the normal operating level with cyclical fluctuation of one to two feet below the operating level at intervals of seven to ten days during the mosquito breeding season. Where inflows are inadequate for the cyclical fluctuation, a gradual recession sufficient to keep the water edge below the encroaching vegetation can be used. A combination of cyclical fluctuation and seasonal recession is planned for some reservoirs.

Shore Line Maintenance: Shore line maintenance includes the control of objectionable vegetation and the removal of drift and flotage. The well-known history of the water hyacinth and its rapid spread in our southern coastal waters is indicative of the problem posed by aquatic plants. They should not be overlooked and the species known to greatly increase the mosquito breeding potential should be kept under control. Aquatic vegetation to be encouraged

for utilization by water-fowl should be selected with care and include only those species that do not greatly increase the mosquito potential of the area. Many species, including water hyacinth, alligator grass, water primrose, lotus, willow, button ball and willow weed, are now recognized to be detrimental to fish and wildlife. Therefore, representatives of the owner of the reservoir, the health agency and the fish and wildlife agency should study the problem jointly and formulate a cooperative plan whereby the health hazards will not be increased, the fish and wildlife values will be improved and the cost of reservoir operation will not be prohibitive.

Much progress has been made in connection with the control of objectionable vegetation. The advantage of shade along the shore line is now recognized. The 2, 4-D acid, the 2, 4, 5-T acid, and formulations of these two acids are suitable for the control of various types of plants. However, these materials must be used with precaution as they may drift to nearby fields and cause damage to broad leaf plants, such as cotton and tomatoes.

Rebrushing of the marginal areas immediately preceding the filling of a reservoir and annually thereafter was formerly a routine practice but is no longer considered essential. Such operations are now limited to removal and control of objectionable woody, aquatic vegetation, including willow and button ball.

The removal of drift and flotage can be minimized through the utilization of a spring surcharge for stranding these materials above the operating water level. Disposal of the remaining drift and flotage can be carried out when the water is at a low stage. Reservoirs with relatively constant water levels are special and drift and flotage removal must be performed with derrick boats or draglines on boats or on the bank.

Larviciding: Larvicides are applied where other methods of mosquito control cannot be utilized and for emergency conditions. The first materials used were mixtures of oils that had to be applied at rates of upward of 40 gallons per acre. Methods of application included the knapsack sprayer carried by a man, dispersal of the oil mixture under air pressure from tanks carried in boats, and finally dispersal of the oil mixture mixed with water by the use of water pumps. About 1920 it was learned that Paris green was an effective larvicide for the Anopheles larva. The Paris green, diluted with road dust, lime or soapstone, was applied in dust form with knapsack-type blowers, with power-driven blowers, and by airplane. The approximate cost (1953) per acre of larviciding with these materials and by these methods are as follows:

Mixtures of Oil	
By Knapsack	$7.20
By Boat	4.25
Paris Green in dustform	
By Knapsack blower	$0.95
By Power-driven-blower	1.20
By airplane	0.75

Developments during World War II and subsequently have greatly increased the efficiency and lowered the unit cost of mosquito control with larvicides. The application of DDT at a rate of 0.05 to 0.20 pounds per acre in solutions containing from 0.5 to 20.0 percent DDT by weight and the obtaining of effective control even in uncleared areas are not yet accepted by all health workers. However, the author was convinced of the effectiveness of DDT as early as

1944 and has obtained satisfactory mosquito control in uncleared areas with an application rate of 0.15 pounds DDT per acre applied in aerosol form from an airplane. The DDT applied in spray form is also effective. The cost of larviciding with DDT (1953) applied by airplane is less than 25 cents per acre. The cost of larviciding with DDT in oil applied from boats is approximately $2.90 per acre and applied from knapsack is about $0.90 per acre. The use of light knapsack jet propulsion fogging equipment will reduce this cost to about $0.50 per acre.

Secondary Measures: Secondary measures of malaria control are sometime utilized. The mosquito-proofing of dwellings has been found to be effective in reducing the malaria transmission potential by 40-60 percent. The treating of all buildings with a material having a residual effect on mosquitoes has been evaluated to reduce the malaria transmission potential by 90 percent or more. The cost of the former is approximately $50 initially and $10 annually per house and of the latter approximately $5.00 per premise per application.

From the above it can be realized that malaria control on reservoirs requires planning and that with proper planning the possibility of a reservoir increasing the malaria transmission hazard is substantially less now than it was prior to 1945.

Planning for malaria control on a reservoir should precede construction. Accurate maps of the reservoir and adjacent areas are required. These maps should include contours below the surcharged water level, all dwellings and developments with facilities for overnight use located within one mile of the proposed shore line and all ponded and marshy areas in the zone of drawdowns and within two miles of the shore line of the normal operating water level. Preimpoundment malaria studies where the malaria potential is high should be for a period of about four years' duration in order to ascertain possible variations caused by weather conditions. For a reservoir located in an area where the natural malaria transmission potential is low, the study need cover only one year prior to impoundment. Where malaria is prevalent its rate of incidence should be determined by examination of blood smears from a well distributed portion (15-25 percent) of the residents of the area. All ponded and marshy areas of the reservoir and vicinity thereof should be inspected to determine their mosquito production potential.

The planning should anticipate postimpoundment use of the reservoir and adjacent areas. Project land to be utilized during night hours should be one mile or more from portions of the reservoir or adjacent areas where the mosquito breeding potential is great. The plan should also take into consideration the purpose of the project, initial cost of preparation of the reservoir, the annual cost of malaria control, and the various methods of malaria control.

Mosquito-Transmitted Diseases Other Than Malaria

The possibility that a reservoir may increase the potential of transmission of mosquito borne diseases other than malaria should be recognized. However, to date there has been little or no evidence that reservoirs have increased the potential of the transmission of these diseases. It is known that Culex tarsalis mosquitoes are capable of transmitting encephalitis (sleeping sickness) but this mosquito does not breed profusely in reservoirs, especially those in the southeast. The Mansonia family of mosquitoes has under laboratory conditions transmitted encephalitis but there is no conclusive evidence that these mosquitoes have transmitted this disease in the United States under

natural conditions. The Aedes aegypti, the transmitter of yellow fever and dengue fever does not breed in ground pools, ponds, lakes and impounding reservoirs. Nevertheless, these potentials should be considered in the planning for reservoirs. There are many species of mosquitoes. Their characteristics, flight range and places most suitable for their production vary greatly. The Aedes aegypti seldom travels over 500 feet whereas the Aedes sollicitans have a flight range of 40 miles or more. The Anopheles quadrimaculatus, the malaria vector of the Southeastern States, has a flight range of over one mile but there is little evidence that this species has transmitted malaria at distances much greater than one mile. Some mosquitoes, including Anopheles, breed in clean, warm water, such as that of reservoirs, others in treeholes, and others in water heavily polluted with organic matter. The Mansonia mosquito larva lives by piercing the roots and stems of certain aquatic plants. Larvicides applied for action at the water surface are not effective for the Mansonia larva and larvicides applied on a volume for volume ratio are too expensive for routine use and some are detrimental to fish. The most practical method of control for Mansonia breeding is through the eradication or control of the host plants.

Mosquito Nuisance

Although most people object to mosquito bites, they will not refrain from visiting areas where mosquitoes are prevalent and will not finance mosquito control where the per capita cost is excessive. Mosquito control for the elimination of the nuisance of mosquito bites is generally limited to densely populated areas and is not provided for sparsely settled rural areas. General mosquito control is not provided on a reservoir-wide basis but is carried out where the population density and public use will justify the cost and provided that local interests perform mosquito control for the areas in the vicinity of the reservoir.

Environmental Sanitation Problems

Environmental sanitation problems of reservoir management are those of the disposal of sewage, garbage and refuse from cabins, lodges, concessions, house boats and cruisers; water supply for cabins and lodges; and protection of areas used for swimming and public access from pollution. The lease or permit for use of an area adjacent to the reservoir should contain a provision that the user will dispose of the sewage, garbage and refuse in accordance with requirements of the State Health Department. Domestic sewage should be adequately treated and, if possible, the effluent should be disposed of by ground absorption. Similarly, there should be a provision that the water supply will be developed in accordance with recommendations of the health agency. Owners of house boats and cruisers should be required to dispose of the sewage, garbage and refuse at selected areas on shore. In some instances settled sewage may be released in areas remote from swimming beaches and public access points for disposal by dilution. Anchorage areas, especially those for occupied boats, should be selected whereby swimming beaches and access points will not be affected.

The plans for the reservoir project should also take into consideration stream flows below the dam. The minimum discharge of water relatively free of organic material should be sufficient to prevent an increase in the downstream pollution problems and safeguard fish life. It is often possible

to develop a project whereby the downstream pollution problem will be greatly improved. As an example, the pollution abatement program in the Cumberland River Basin has been particularly effective since the construction of the upstream reservoir projects by the Corps of Engineers. The pollution problem at Nashville, Tennessee, and below is acute with normal low flows of 350 to 400 cubic feet per second but possible regulated discharges from the Wolf Creek, Dale Hollow and Center Hill projects can provide a minimum flow of 2000 cfs and an average daily flow of 3000 cfs during the period of low natural stream flow. The Buford project under construction on the Chattahoochee River above Atlanta, Georgia, also will increase the minimum and average low-water season flows downstream. Similarly, the majority of reservoir projects having storage for power production improve the downstream low-water flow.

Single purpose flood control reservoirs seldom have sufficient storage that can be drawn on to increase materially downstream low-water flow nor inflow sufficient during periods of little runoff for fluctuating the water level on a cyclical schedule for mosquito control. Usually, however, gradual recession of a few feet during the mosquito season can be accomplished. This will provide an increase in down stream flow and even though the increase may not be large it will reduce the pollution problem, improve the conditions for fish and increase the firm water supply of nearby cities.

CONCLUSIONS

Reservoir management does have sanitary engineering problems. The most important of these problems for reservoirs in the tropical and temperate zones is that of malaria control. However, with proper planning, operation and management, a reservoir will not increase the malaria transmission hazards of the area. Sanitation on and around the shore line of a reservoir can be maintained through cooperation with state and local health agencies. Discharges from reservoirs tend to reduce the downstream pollution conditions as such discharges are generally greater than the low-water flow of the streams. Coordination with health agencies, fish and wildlife agencies and other agencies is essential in order to prevent the creation of health hazards, improve fish and wildlife values and to obtain as many benefits from the reservoir as are economically feasible.

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The technical papers published in the past twelve months are presented below. Technical-division sponsorship is indicated by an abbreviation at the end of each Separate Number, the symbols referring to: Air Transport (AT), City Planning (CP), Construction (CO), Engineering Mechanics (EM), Highway (HW), Hydraulics (HY), Irrigation and Drainage (IR), Power (PO), Sanitary Engineering (SA), Soil Mechanics and Foundations (SM), Structural (ST), Surveying and Mapping (SU), and Waterways (WW) divisions. For titles and order coupons, refer to the appropriate issue of "Civil Engineering" or write for a cumulative price list.

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a. Beginning with "Proceedings-Separate No. 200," published in July, 1953, the papers were printed by the photo-offset method.
b. Presented at the Miami Beach (Fla.) Convention of the Society in June, 1953.
c. Presented at the New York (N.Y.) Convention of the Society in October, 1953.
d. Beginning with "Proceedings-Separate No. 290," published in October, 1953, an automatic distribution of papers was inaugurated, as outlined in "Civil Engineering," June, 1953, page 66.
e. Discussion of several papers, grouped by divisions.
f. Presented at the Atlanta (Ga.) Convention of the Society in February, 1954.

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